A BRIDLE-LESS TRAWL AND FINE-MESH PURSE SEINE FOR SAMPLING PELAGIC COREGONINE LARVAE WITH OBSERVATIONS OF SPATIAL DISTRIBUTION AND ABUNDANCE

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Evans, D. O., and P. R. Johannes. 1988. A bridle-less trawl and fine-mesh purse seine for sampling pelagic coregonine larvae with observations on spatial distribution and abundance. Ont. Fish. Tech. Rep. Ser. No. 27. 19 p.

Two fishing gears are described for quantitative sampling of pelagic coregonine larvae in lakes: a bridle-less trawl and a fine-mesh purse seine. The trawl is effective for nearshore and offshore sampling and can be fished at the surface or at depth. The purse seine is generally limited to use at depths greater than 5 m. Specifications and component costs for both gears are provided. Catch data for larval and juvenile lake whitefish, *Coregonus clupeaformis*, and lake herring, *Coregonus artedii*, from Lake Opeongo, Ontario, are presented to illustrate the effectiveness of these samplers. In paired tows, the bridle-less trawl caught 2-3 times more larvae of both species than a bridled Faber trawl. The purse seine, however, was more efficient than the bridle-less trawl, estimated areal densities of larvae being 2-7 times greater based on purse seine catches. This difference is largely explained by the much greater depth coverage of the purse seine. The purse seine catches were also significantly less variable.

Key words: coregonine larvae, sampling, bridle-less trawl, purse seine

INTRODUCTION

Numerous gear types have been described for sampling larval fishes. These include purse seines (Hunter et al. 1966; Durkin and Park 1967; McDonald 1969; Murphy and Clutter 1972; Johnsen and Sims 1973; Hartt 1980) and a wide variety of trawls (e.g. Nellen and Schnack 1975; Bowles and Merriner 1978; Bagenal and Nellen 1980; Hatch and Underhill 1984). These gears have various limitations, however, especially in small lakes where pelagic fish larvae, even within species, often occupy varied habitats during their early ontogeny. Avoidance of gears by actively swimming larvae, inaccessibility of samplers to littoral habitats, and failure of some gears to adapt to small-boat operation are the major problems encountered.

Our purpose is to describe the construction, deployment and effectiveness of two sampling gears, a bridle-less trawl and a fine-mesh purse seine, which together largely overcome the above sampling problems. The trawl is a single net modification of a bongo net design by Smith and Richardson (1977), and the purse seine is a modification of nets described by Hunter et al. (1966) and Murphy and Clutter (1972).

The trawl net design is the product of extensive field testing by marine workers and has been adopted for our purposes because its evenness of flow and filtration minimizes avoidance as well as escapement or extrusion of organisms through the meshes (Smith and Richardson 1977). The marine version of this net is a bongo net design which is towed by a single medial cable and requires a heavy davit and winch; gear that is not suitable for work in small lakes. Our net frame and deployment procedure facilitates operation of a single net from a small boat, while maintaining the advantages of bridle-less operation and the excellent filtering characteristics of the original net design.

The purse seine was adapted for use in small lakes to complement use of the trawls, which are effective for both shallow water and offshore operation, but which are prone to avoidance by larger larvae. The purse seine is a large volume grab sampler which is less prone to avoidance (Murphy and Clutter 1972). The purse seine also facilitates extended sampling of the larval and post-larval life stages beyond the period of vulnerability to trawls.

Catch data are presented for larval lake whitefish, *Coregonus clupeaformis*, and lake herring, *Coregonus artedii*, from Lake Opeongo, Ontario, to illus-

trate the effectiveness of the gears. Effective sampling depends on some knowledge of the distribution of the target species, accordingly observations on the spatial distribution and abundance of the larvae are included.

MATERIALS AND METHODS

BRIDLE-LESS TRAWL: DESCRIPTION

The trawl net (Fig. 1a) is identical in dimension to that described by Smith and Richardson (1977), but the towing frame and bridle is a new design. Each trawl is deployed singly, supported by an external aluminum frame (Fig. 1b, c) which eliminates interference from bridle lines ahead of the net opening. The net is secured to the net frame and collar by two stainless steel band clamps. The net collar is made of 2.0 mm thick stainless steel and is attached to the aluminum frame by steel pins which are welded directly to the collar. This design allows the net mouth to rotate into a vertical position while being towed. Two 4.5 kg depressors are suspended from the trailing corners of the net frame to provide weight and stability. The cod-end bucket of the trawl consists of 10 cm diameter plexiglass pipe, with two rectangular straining windows covered with 500 micron Nitex mesh (Fig. 1a). The bucket is capped with an ABS fitting and screw plug, and is attached to the net with steel band clamps. The catch is removed by unscrewing the end plug of the cod-end bucket. Two trawls are fished simultaneously, one on each side of the boat.

The nets are suspended by paired towing lines from 3 m booms (Fig. 2). Each tow line is secured near the end of the boom, passes through swivel blocks on the leading corners of the trawl frame, returns through a ring on the boom, and is tied off at a cleat on the gunwale (Fig. 3). The swivel blocks provide for self-adjustment in the length of the two arms of the tow line allowing the net frame to remain in position during changes in boat direction. The swivel blocks also enable the fishing depth of the trawl to be manually reset by lengthening or shortening the tow line at the point of attachment at the gunwale. Once the tow lines are set for a desired fishing depth, a davit and manual winch are used to deploy and retrieve the trawl (Fig. 2).

Flowmeters (General Oceanics) are employed to monitor speed, distance travelled and filtration efficiency. One is located in the opening of the starboard net and is connected via cable to a remote readout at the operator's station. The second flowmeter is tethered to the starboard towing boom. The nets are positioned about 2.5 m from the gunwale, well clear of the turbulence caused by the bow of the boat.

Components, materials and 1987 costs for construction of a single trawl net, as well as associated rigging, accessories and labour cost for assembly of the net are given in Table 1.

DEPLOYMENT OF THE TRAWL

The paired trawls are normally towed for five min at speeds ranging from 1.5 to 1.8 m/second. The nets have been fished at depths to 4.0 m, but they are usually towed about 5 cm below the water surface.

To deploy the nets, the boat is stopped on station and the nets are lowered into the water using the davit winches until the weight is taken up by the preset tow lines and the davit cable is slack. The boat is quickly brought to towing speed, and the trawls rise to their preset trawling depth (Fig. 4). When the tow time has elapsed, the boat is stopped and the nets are hoisted out of the water using the davit winches. After careful washing of the lower portion of the net, the cod-ends are emptied into separate light coloured basins. The cod-end bucket is recapped and the washing procedure is repeated. The catch is removed and immediately preserved in 10% buffered formalin. Flowmeter readings are recorded at the beginning and end of each tow for exact determination of average speed, distance travelled and net filtration efficiency. Periodically, as dictated by the flowmeter information and visual inspection, the nets are washed using onboard water pumps.

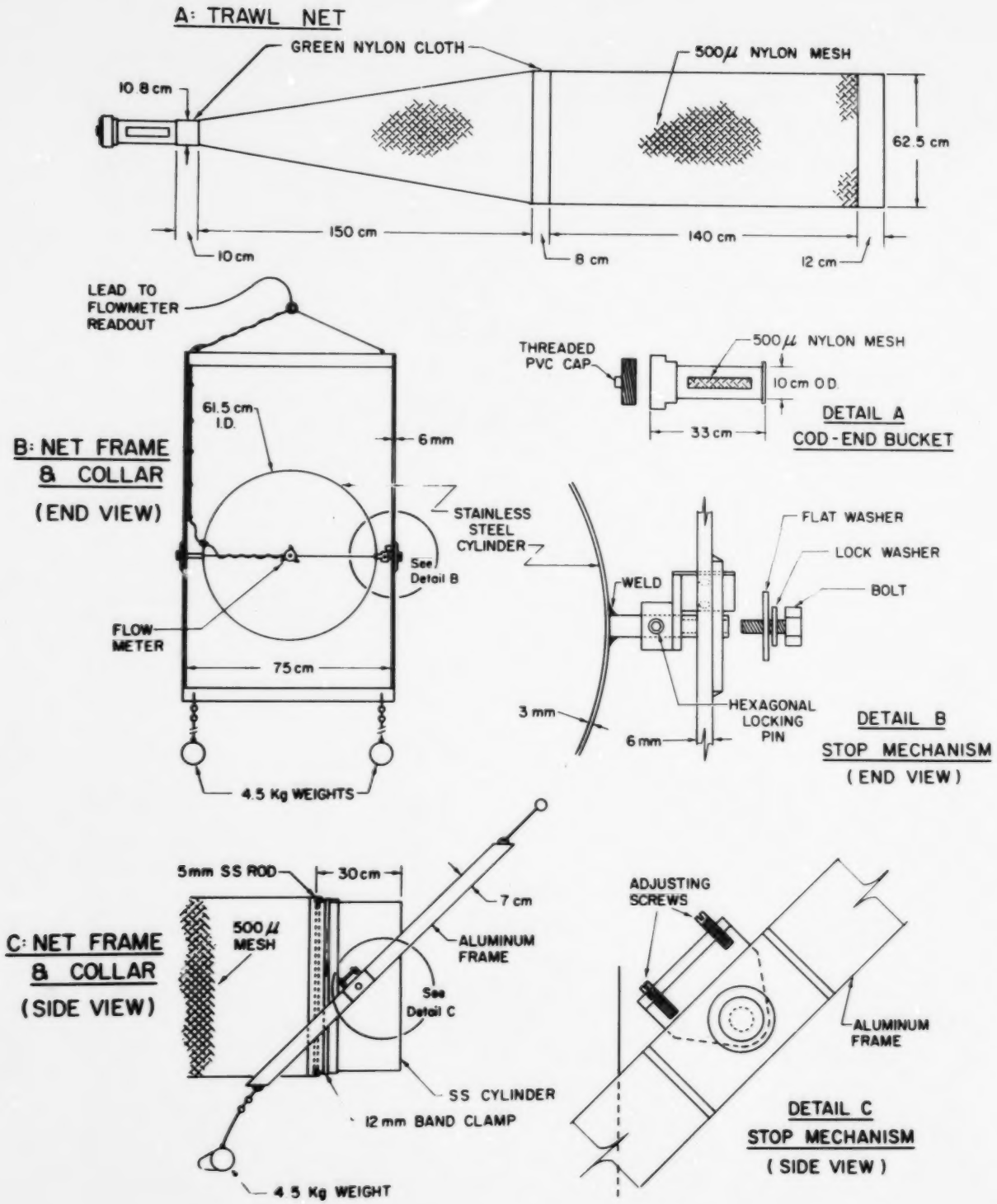

Fig. 1. Drawing of the bridle-less trawl showing dimensions and materials for the net (A), cod-end bucket (Detail A), and end view of the net frame and collar (B), axle and stop mechanism (Detail B) which allows the net to rotate to a vertical towing position but which prevents unnecessary rotation when the net is lifted from the water, and side views of the net frame and collar (C) and the stop mechanisms (Detail C).

Fig. 2. Side view of 7 m work boat showing towing booms and davits in upright positions.

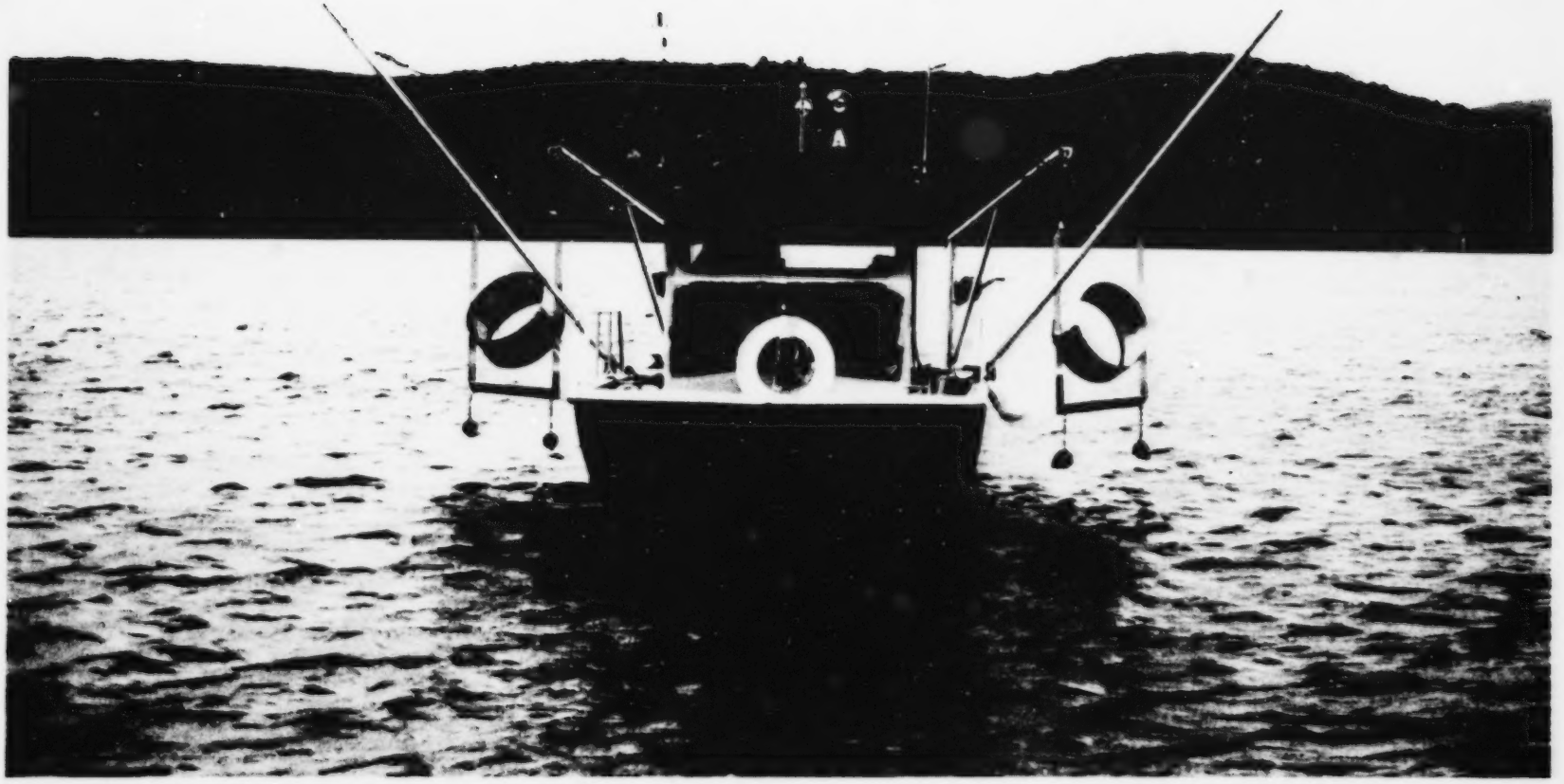

Fig. 3. Head-on view of fully rigged trawls in running position. Booms are lowered to a preset horizontal position for trawling by reversing davit winches to achieve the desired tow depth.

Table 1. Cost listing of larval trawl components, associated rigging and accessory equipment.

Component	Material description	Quantity	1987 cost[a]
Net and Frame Assembly			
Netting	500 micron Nitex screening	6 m^2	125.00
Netting reinforcement	Dark green nylon cordura cloth	0.5 m^2	6.00
Net mouth cylinder	14 gauge 304 stainless steel	1	180.00
Band clamps	1.5 cm wide x 2 m long stainless steel	2	15.00
Net frame	6 mm x 7 cm aluminum	1	260.00
Net frame stop	Stainless steel	1	80.00
Net frame blocks	Single swivel block for 1.27 cm (1/2") rope	2	55.00
Cod-end bucket	Clear 6 mm x 10 cm dia. acrylic tubing	0.3 m	18.00
Cod-end plug	10 cm dia. ABS inspection fitting and threaded plug	1	8.00
Cod-end line	3 mm yellow 3-strand polypropylene	15 m	1.50
Depressors	4.5 kg steel cannonball downrigger weights	2	30.00
Net towing rope	1.27 cm (1/2") black 3-strand polypropylene	30 m	18.00
Supporting Hardware			
Towing boom	5 cm dia. cadmium plated steel conduit 3 m long	1	85.00
Boom mounting bracket	Aluminum base with steel flanges and axle pin	1	65.00
Boom rigging	3 mm stainless steel cable	8 m	10.00
Boom suspension block	Double halyard turning block for 1.27 cm (1/2") rope	1	40.00
Boom suspension rope	1.27 cm (1/2") black 3-strand polypropylene rope	10 m	6.00
Davit	Steel davit - 250 kg capacity	1	390.00
Davit winch	800 kg hand winch with friction brake	1	75.00
Winch cable	3 mm stainless steel	15 m	18.00
Wire block	Block with steel sheave for 3 mm wire cable	1	25.00
Miscellaneous hardware	Rigging turnbuckles (4), shackles (2), depressor swivel clips (2), wire cable thimbles and sleeves (5) and 6 mm x 3" eye bolts for boom		70.00
Flowmeters			
Flowmeters	Model 2031G - General Oceanics	2	1550.00
Flowmeter cable	General Oceanics	10 m	575.00
Flowmeter readout	Model 2035HB analog remote speed readout - General Oceanics	1	2090.00
Assembly Labour			
Labour	Cutting and sewing net parts	5 hr	80.00

[a]Canadian dollars, January 1987 (PST not included).

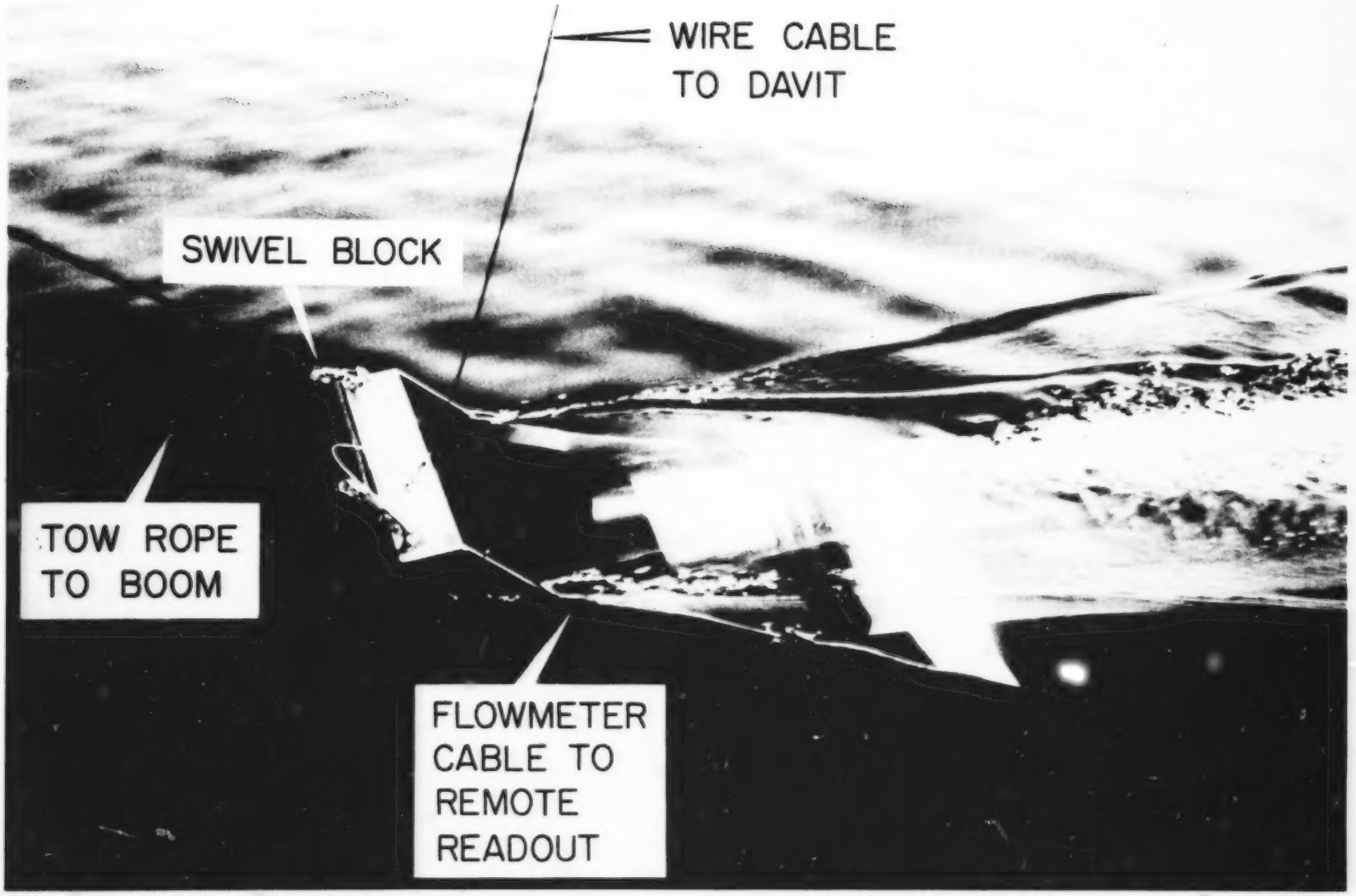

Fig. 4. Photograph of the starboard trawl fishing at the surface. Tow ropes are preset for the desired depth at which point the cable to the davit is slack. Flowmeter cable and paired swivel pulleys on the net frame are also shown.

FINE-MESH PURSE SEINE: DESCRIPTION

Dimensions of the purse seine were determined by three primary requirements: that the net be manually operable from a relatively small vessel; that a nearshore depth of 5 m be accessible to fishing; and that larval and post-larval fish, 5-30 mm in length, be fully vulnerable to capture. Key physical design considerations for net construction include: length to depth ratio to allow effective pursing; overall net shape to facilitate purse line retrieval; correct buoyancy to weight ratio to provide rapid sinking and enclosure of the water volume while achieving effective flotation and maintaining a barrier to fish escapement at the surface; durability of seams and selvedge (border) to maximize strength with minimum bulk; and dark coloration to minimize visibility and fish escapement.

The net is constructed of three longitudinal panels of dark green nylon netting with 1 mm square mesh openings. Each panel is 1.7 m wide with panel length varying from 31.5 m in the upper panel to 27.7 m in the lower panel (Fig. 5). Specifications and costs for the material components of the net are given in Table 2.

When correctly set, the purse seine produces a circular enclosure with a diameter of 10 m and an area of 78.5 m^2. The total net depth of 5 m was established to allow inshore use but still permit effective pursing. Based on commercial purse seine designs (Iitaka 1971), a float-buoyancy-to-lead-weight ratio of 3.5:1 was used. We employed 31.8 kg of float buoyancy to 9.1 kg of lead weights.

The presewn length of the top panel of the net is 37.8 m, of which 6.4 m of mesh is employed to form pockets around the floats. Initially, each panel of netting is cut to size, the top panel tucks are sewn and the three panels are joined together using a triple stitch (Fig. 5). The perimeter of the net is double hemmed and folded strips of heavy nylon cordura are applied to the net sides as selvedge. Nylon cordura patches serve to secure the float and lead lines to the net, and provide proper spacing of floats and leads (Fig. 5). Purse rings with 40 cm bridles are tied to the lead line completing the purse seine assembly.

DEPLOYMENT OF THE PURSE SEINE

In preparation for setting, the purse rings are arranged sequentially along the port gunwale so that the purse line can run through them freely during the set. The remainder of the net is loosely piled on the deck so that it will trail off the stern of the boat without tangling. One end of the net is secured to the boat, while the other is attached to a 125 litre plastic pail which acts as a sea anchor to minimize towing of the net during a set. The purse seine is set into the wind as the boat traces a circular path slightly exceeding a 10 m diameter circle (Fig. 6). The net is let out over the stern by hand, while the boat operator assists by clearing and letting out the purse line. Once the net is deployed, the sea anchor is detached from the purse seine and the net is secured to the port side of the boat.

Pursing is accomplished by manually drawing in the stern end of the purse line. The float line is simultaneously, but more slowly retrieved, reducing the deployed net diameter. When pursing is complete, all weights and rings are lifted from the water confining the catch to the middle section of the net wall. Both ends of the float line are gradually retrieved, while netting is lifted vertically from the water and gently shaken to dislodge any fish or debris adhering to the mesh. The impounded area is ultimately reduced in volume to a few litres, allowing the catch to be easily dip netted. Less than 10 min are required from initiation of a set to formation of the net pocket containing the catch. Time spent removing and sorting fish depends on the numbers and size of fish caught and the presence of other organisms, some of which may cause clogging of the mesh. For example, *Holopedium gibberum*, a gelatinous zooplankter, is particularly troublesome when abundant because it is retained by the small mesh and greatly increases removal time.

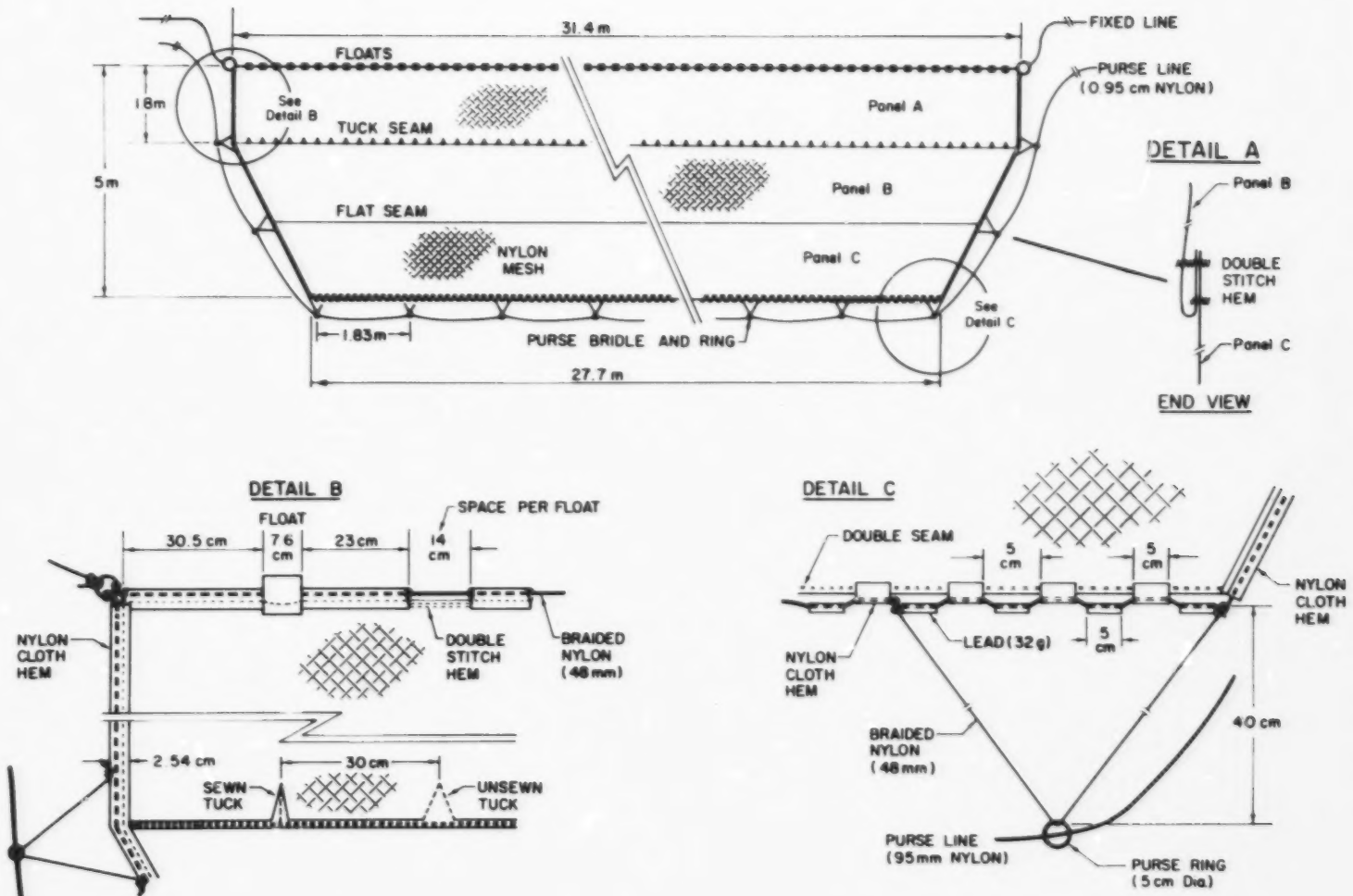

Fig. 5. Drawing of the purse seine showing dimensions and materials for the net and construction details for the seams (Detail A), float line (Detail B) and lead and purse lines (Detail C).

Table 2. Complete listing of purse seine components and costs.

Components	Material description	Quantity	1987 cost[a]
Netting	Dark green nylon mosquito screening 1.0 mm square mesh	100m x 1.8m	350.00
Flotation	Sponge floats 7.6 x 7.6 cm with 1.3 cm hole	101	80.00
Weights	Cylindrical lead weights 5.24 cm long with 0.7 cm hole	273 (9.1 kg)	45.00
Purse rings	Galvanized steel rings 5 cm dia, 0.6 cm thickness	20	12.00
Float line	0.476 cm (3/16") dia braided nylon line	33 m	9.50
Lead and side lines	0.476 cm (3/16") dia braided nylon line	40 m	12.00
Purse lines	0.953 cm (3/8") dia braided nylon rope	45 m	50.00
Skiff line	1.27 cm (1/2") dia 3-strand polypropylene rope	30 m	16.50
Ring bridles	0.476 cm (3/16") dia braided nylon line	20 m	6.00
Lead line attachments	5 x 5 cm nylon cloth patches	274	8.00
Float line attachments	23 x 10 cm nylon cloth pieces	100	26.50
Side selvedge	5.5 x 0.1 m nylon cloth strips	2	12.50
Top corner selvedge	30.5 x 10 cm nylon cloth strips	2	1.50
Labour	Cutting and sewing of net components	16 hr	256.00
		Total	$885.50

[a]Canadian dollars, January 1987 (PST not included).

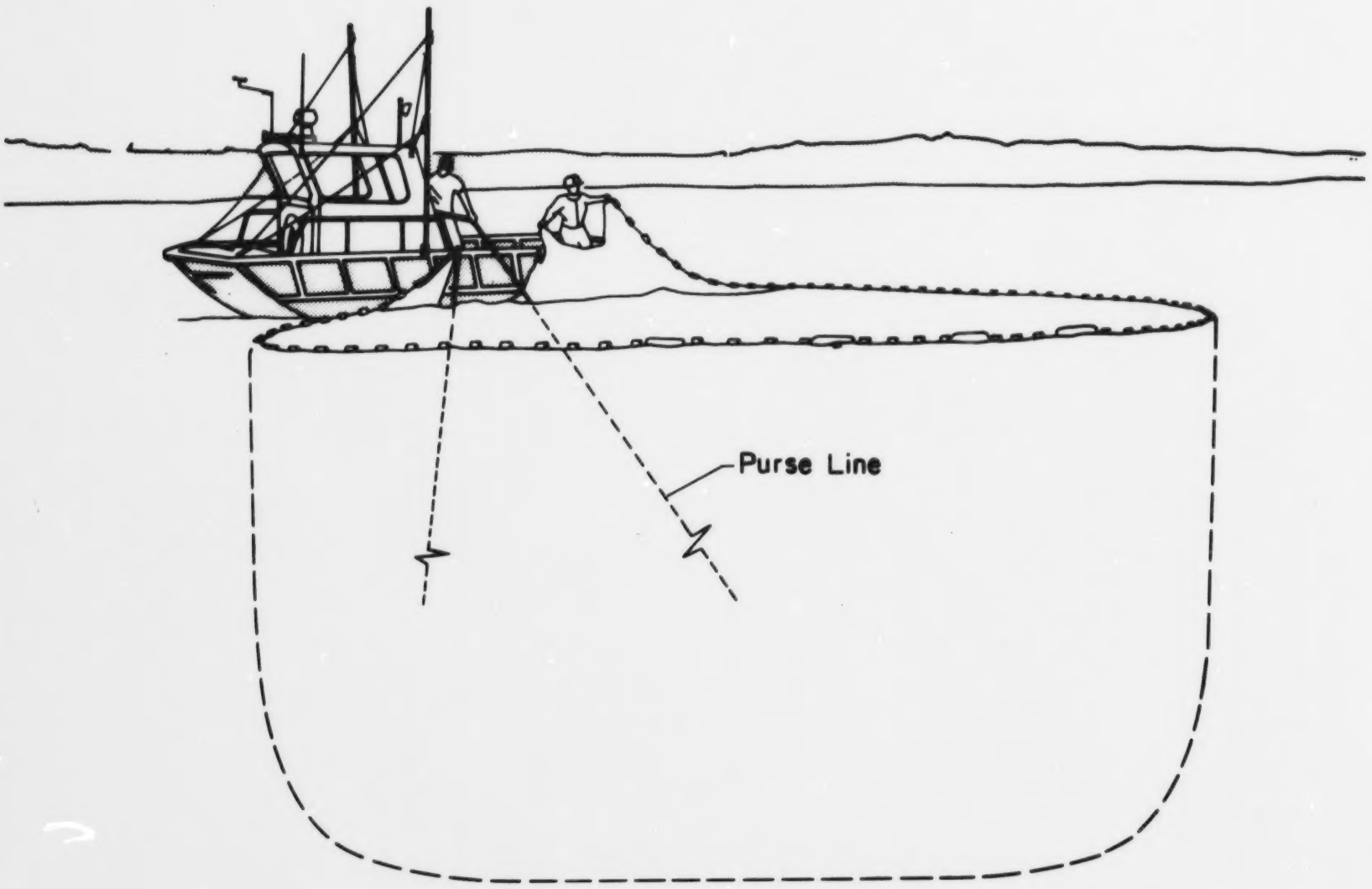

Fig. 6. Work boat and fully deployed purse seine.

GEAR COMPARISONS

Bridle-less trawl versus a bridled Faber trawl

A series of 10-15 paired tows were made on each of four sampling dates from April 29-June 4, 1987, to compare the catch efficiencies of the bridle-less trawl with a bridled Faber trawl of similar diameter (Faber 1968). The Faber net had been used during earlier surveys of larval lake whitefish, lake herring and yellow perch, *Perca flavescens*, in Lake Opeongo (Cucin and Faber 1985). A single pair of bridles are employed in the Faber net. The bridles do not obstruct the net opening but do disturb the water immediately preceding and above the opening.

On each date, repeated paired tows were made using the two nets in areas of the lake known to be inhabited by larval coregonines. The nets were deployed on opposite sides of the boat in the same manner described above for the paired bridle-less trawls, with the exception that a single external flowmeter was used to monitor net speed and distance travelled. All tows were made offshore to avoid density gradients of larvae that were occasionally observed near shore. The captured larvae were identified to species and total lengths were measured.

Bridle-less trawl versus the fine-mesh purse seine

A series of trawl and purse seine samples were collected in one area of Lake Opeongo during the week of June 7-10, 1983. The sizes and variances of the catches and the size distributions of the captured lake herring and lake whitefish larvae were compared to assess the relative effectiveness of the two samplers.

RESULTS AND DISCUSSION

DISTRIBUTION OF THE LARVAE

The bridle-less trawl was effective in capturing larval lake whitefish and lake herring. Both species congregate near the surface of lakes soon after hatching (Hart 1930; Einsele 1963; Faber 1970; Hoagman 1973). In Lake Opeongo, Ontario, we captured both species near the surface, but some near-surface stratification of larval abundance was observed (Table 3). Lake herring were caught at the surface, and at 1 and 2 m in replicate depth series on four different days, while lake whitefish were caught at the surface only, with the exception of a single larva that

Table 3. Catches of larval lake herring and lake whitefish at three depths in 5 min paired bridle-less trawls in Lake Opeongo during 1983. The catches are totals over the two nets used in each tow.

Date	Time of day (EDT)	Area sampled (m^2) $\bar{x} \pm S$	Net velocity m/sec $\bar{x} \pm S$	Species	Sampling depth: Surface Number caught	Surface Length $\bar{x}$ (mm)	Surface ±S	1.0 m Number caught	1.0 m Length $\bar{x}$ (mm)	1.0 m ±S	2.0 m Number caught	2.0 m Length $\bar{x}$ (mm)	2.0 m ±S
May 21	1800-2000	305 14	1.75 0.09	Lake herring	113	12.1	2.1	19	12.2	2.0	10	10.4	1.0
				Lake whitefish	8	13.5	0.9	0			0		
May 28	1630-1800	316 4	1.80 0.01	Lake herring	2277	15.6	2.0	56	15.0	2.0	13	11.6	2.4
				Lake whitefish	77	15.5	0.8	1	16.1		0		
May 30	1130-1330	304 7	1.82 0.09	Lake herring	211	13.7	2.7	55	11.1	1.1	15	10.4	0.7
				Lake whitefish	6	15.6	1.7	0			0		
May 30	1330-1500	309 5	1.82 0.00	Lake herring	115	14.7	3.0	17	11.5	1.3	15	10.2	0.8
				Lake whitefish	4	15.7	1.0	0			0		

was caught at 1 m. Length frequency distributions varied for lake herring larvae caught at various depths, the largest larvae being caught nearest the surface (Table 3, Fig. 7). In each depth series, lake herring larvae captured at 2 m were smaller than those caught at the surface (two-sample t tests) and, in 3 of 4 cases, the lengths of larvae caught at 1 m were intermediate.

Stratified random sampling revealed marked differences in catches of larvae between the nearshore (<5 m depth) and offshore (>5 m depth) strata within one sector of the East Arm of Lake Opeongo (Table 4). The coefficient of variation of the catches were the same or lower in the offshore versus nearshore areas, but densities tended to be much higher in the nearshore areas for both species during the initial 2-3 weeks after hatching. During the third and fourth weeks of sampling in 1983, larval densities were similar in both strata.

Comparison of the paired tows indicated strong positive correlation between the catches within species during the initial 2-3 weeks after hatching, but only weak correlation thereafter. Visual observations of swimming larvae revealed a

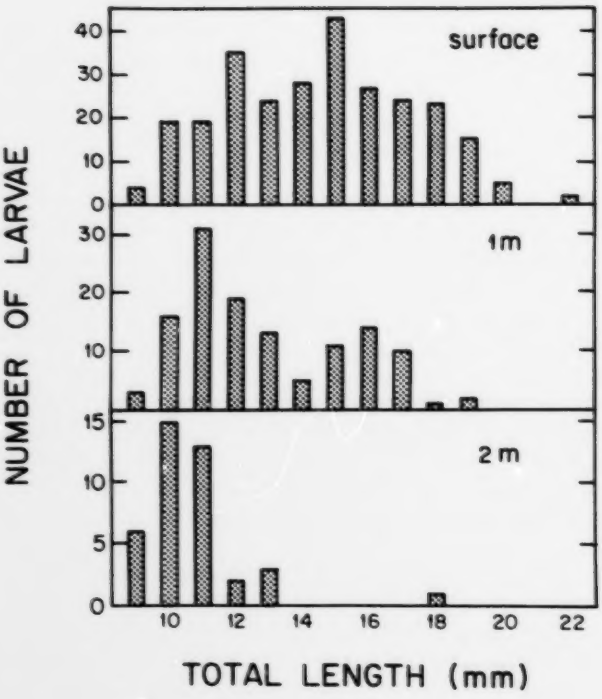

Fig. 7. Length frequency distributions for larval lake herring samples captured at the surface, 1 m and 2 m, May 21-30, 1983.

Table 4. Bridle-less trawl catches of larvae of lake whitefish and lake herring in the East Arm of Lake Opeongo during 1983. Geometric mean catch and coefficient of variation is for the combined catches of paired tows adjusted to a standard tow distance of 500 m. The catch per m^2 is the number caught per unit area of lake surface adjusted to correspond to a rectilinear net 61 cm square rather than the actual circular net area of 61 cm diameter, and represents the density of larvae in the 0-61 cm depth stratum only.

		Nearshore stratum				Offshore stratum			
Species	Date	No. of paired tows	Geometric mean catch	Coefficient of variation	No. of larvae per m^2	No. of paired tows	Geometric mean catch	Coefficient of variation	No. of larvae per m^2
Lake whitefish	May 12-13	19	19.1	0.50	0.040	14	7.1	0.64	0.015
	21-22	24	8.8	0.67	0.014	16	4.7	0.70	0.010
	28-29	24	1.4	1.40	0.003	16	2.7	0.94	0.006
	June 7-8	22	0.9	1.35	0.002	17	0.7	1.38	0.002
Lake herring	May 12-13	19	240.9	0.18	0.503	14	43.7	0.28	0.041
	21-22	24	105.9	0.47	0.299	16	74.2	0.17	0.155
	28-29	24	39.7	0.42	0.083	16	27.2	0.38	0.057
	June 7-8	22	10.4	0.93	0.022	17	15.8	0.43	0.033

change from non-schooling to schooling behavior about 3-4 weeks after hatching. Catches in the starboard trawl with the flowmeter were similar to the port trawl without a flowmeter for the 130 paired trawls at offshore stations for both species over four dates in 1983. Analysis of variance revealed no effect of the flowmeter on the number of larvae caught, but significant differences were found between sampling dates ($F = 12.76$, 3 and 244 d.f.) and species ($F = 190.38$, 1 and 244 d.f.) (Table 4). Absence of a flowmeter effect indicates that lack of correlation between duplicate tows after 2-3 weeks was related to changes in the distributional characteristics of the larvae, not to a change in the ability of the larvae to avoid the trawls because of the presence or absence of the flowmeter.

A similar pattern of nearshore and offshore distribution over time was observed for lake whitefish and lake herring. Both species were much more abundant nearshore than offshore during the first few weeks after hatching (Table 4). By the third and fourth weeks, concentrations of lake whitefish and lake herring, respectively, were similar in the nearshore and offshore zones (Table 4). The large increase in sampling variation from May 21-22 to May 28-29 for lake whitefish, and from May 28-29 to June 7-8 for lake herring, appears to correspond with the onset of schooling behavior, which was observed by direct visual sightings. The catches also indicate that new recruits entered the lake herring population until at least May 21-22 (Table 4). Examination of the length of the lake herring larvae and the size of their yolk sacs confirmed that new hatchlings continued to enter the lake herring population until early June.

GEAR COMPARISONS

Catches of both lake whitefish and lake herring larvae were consistently higher in the bridle-less trawl than the bridled Faber net in paired tows (Table 5). Mean catches were 2-3 times greater in the bridle-less net with the discrepancy increasing as the size of the larvae increased. Analysis of variance confirmed highly significant differences between the logarithmic catches of the two types of trawls for lake whitefish ($F = 10.35$; $P < 0.002$) and lake herring ($F = 23.30$; $P < 0.0001$). The bridle-less trawl also tended to catch slightly larger larvae although this was only statistically significant in the case of lake herring based on total lengths ($F = 4.57$; $P < 0.03$).

Catches corrected to an areal basis were higher for the purse seine than the bridle-less trawls, because the trawls

Table 5. Comparison of catches (mean ± standard deviation) of larval lake whitefish and lake herring in the bridle-less trawl versus the Faber net in paired tows in Lake Opeongo during spring 1987.

Date	Number of tows	Distance towed m ±S	Net speed $m\ sec^{-1}$ ±S	Mean catch ±S			
				Lake whitefish		Lake herring	
				Bridle-less trawl	Faber net	Bridle-less trawl	Faber net
April 29	10	434	1.44	24.4	9.0	68.9	28.9
		12.4	0.03	0.82	0.57	0.57	0.61
May 6	10	433	1.44	16.8	9.8	169.7	87.4
		16.4	0.05	0.55	0.39	1.07	1.14
May 23	15	436	1.45	0	0	16.3	4.7
		23.3	0.08			0.57	0.75
June 4	15	458	1.53	0	0	20.3	6.1
		31.6	0.11			1.00	1.40

sampled only near the surface and are more prone to avoidance by the larvae (Table 6). Other studies have clearly shown that avoidance of trawls increases as fish body size increases (Clutter and Anraku 1968). Estimated densities of lake whitefish larvae during June 7-10 were 2-3 times greater based on purse seine sampling compared to the trawls. Similarly for lake herring, purse seine catches resulted in estimated densities seven times greater than the trawl catches. The catch differences between gears for the two species are consistent with the greater depth distribution of lake herring and more effective depth sampling by the purse seine.

Size distributions of larvae caught in the trawls versus purse seine for each species were compared by correcting the size of each fish to the common date of June 9. This was accomplished by fitting a growth curve to length data from May 12 to June 10 of the form $L_t = L_{to}e^{G(t-to)}$ where L_t is length at time t, L_{to} is length at time zero (April 15), G is the slope of the growth curve, and t is the time in days from April 15. Size corrected distributions of lake whitefish and lake herring revealed differences between species and gears, reflecting differences in life history of these species and the vertical sampling characteristics of the gears (Fig. 8). Size distributions of lake whitefish in the trawls and purse seine were similar (Kolmogorov-Smirnov two-tailed test, $P = 0.096$), but size distributions for lake herring larvae captured by the two samplers were significantly different (Kolmogorov Smirnov two-tailed test, $P = 0.016$). The purse seine simply captured more small herring than the surface trawl, as expected from Fig. 7. This could be rectified by towing the trawls at multiple depths, but would involve significantly more work to correctly characterize the size distribution of the population. Size differences between the species reflect an earlier hatch date and larger size at hatch of the lake whitefish. These results, of course, only apply up to total lengths of about 20-22 mm, the modal sizes of larvae in our samples. At larger lengths, larval distributions and effi-

Table 6. Comparison of the catches of larval lake whitefish and lake herring in the bridle-less trawl and purse seine in Lake Opeongo during 1983. Catches in the trawls are corrected to tows of 500 m and purse seine catches are number of larvae per set. Catches per m^2 in the trawl have been corrected to correspond to a rectilinear shape 61 cm square, rather than the actual circular net area of 61 cm diameter. Unit area sampled by the purse seine is taken to be 1.5 times the nominal circular area to account for inadvertent towing while the net is being set. Trawl catches are for the 0-61 cm depth stratum only.

			Fish length (mm) mean±S (n)	Nearshore catch				Offshore catch			
				No. of samples	Geometric mean catch	Coefficient of variation	No. of larvae per m^2	No. of samples	Geometric mean catch	Coefficient of variation	No. of larvae per m^2
Lake whitefish	June 7-8	Trawl	20.4 1.5 (67)	22	0.9	1.35	0.002	17	0.7	1.38	0.002
	June 10	Purse seine	21.2 1.9 (29)	11	0.7	1.14	0.006	17	0.6	1.32	0.005
Lake herring	June 7-8	Trawl	19.7 2.8 (200)	22	10.4	0.93	0.022	17	15.8	0.43	0.033
	June 10	Purse seine	18.7 3.4 (200)	11	18.2	0.39	0.155	17	27.3	0.33	0.232

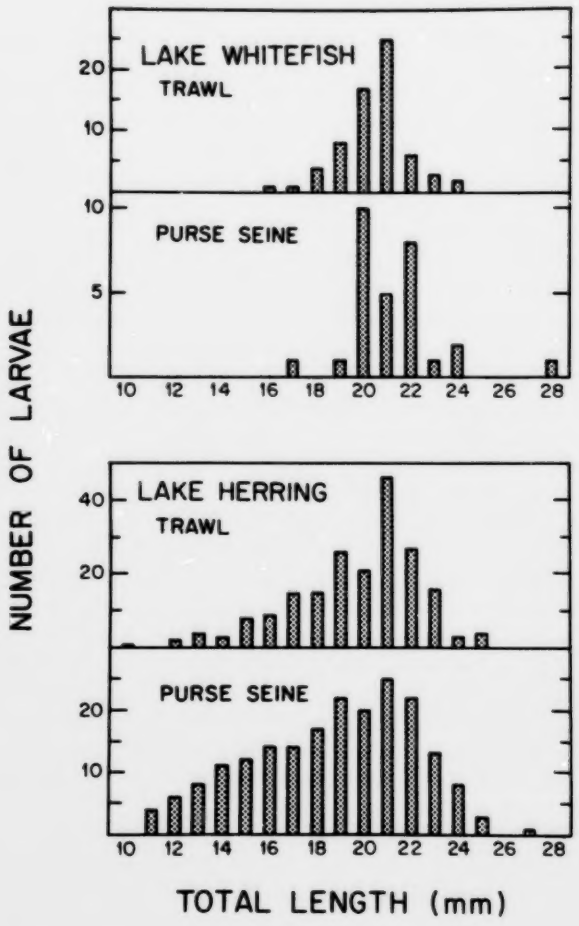

Fig. 8. Length frequency distributions for larval lake whitefish and lake herring captured in trawls and purse seines on June 7-10, 1983. Lengths in each case were corrected to June 9 using growth models for each species based on larvae captured from May 12-June 10, 1983 (see text).

ciencies of the samplers may change. Information on temporal changes in larval distributions and associated changes in gear effectiveness will be published in more detail elsewhere.

CAPABILITIES AND LIMITATIONS OF THE GEARS

The larval trawl and purse seine each have advantages and limitations which determine how and when they can best be employed to quantitatively sample larval lake whitefish and lake herring.

The trawl nets, equipped with a flowmeter, offer a precise measure of the tow distance and, therefore, the area and volume of water sampled. Area and volume sampled by each trawl per 5 min tow is about 300 m^2 and 145 m^3, respectively, when towed at 1.75 m s^{-1}. In addition, the fishing depth of the nets can be accurately determined and adjusted to provide a means of sampling discrete depth strata.

The area and volume of water sampled by the purse seine as well as its effective fishing depth is not known exactly and may vary from set to set depending on the quality of the set and the resultant shape of the fully deployed net. A large volume grab sampler with a sampling volume in the order of 350 m^3, the purse seine samples from the surface to a depth of 5 m. The net samples a nominal area of 78.5 m^2 but, in actual use with the present boat, is estimated (based on graphic models) to actually sample an area 1.5 times that value or about 39% the mean area sampled by the bridle-less trawl during a 5 min tow. Because of its fishing depth, the purse seine cannot be used in the shallow nearshore areas generally available to the trawl without risk of snagging underwater structures.

The purse seine does, however, provide fine-scale horizontal sampling resolution limited only by the set diameter and the number of sets that can be made over a given sampling period. The towed trawl integrates horizontally during a 5 min tow over a relatively long distance (0.5 km) with the minimum horizontal resolution equal to the distance travelled.

It is assumed that the purse seine filters all of the water and captures all of the fish originally contained by the set down to the effective fishing depth, with the exception perhaps of some of the fish under 6 mm in length, such as newly hatched burbot, *Lota lota*, and yellow perch, which may be lost through the 1 mm square mesh. Avoidance of the purse seine by most species is presumed to be minimal, as demonstrated by catches of schools of adult and juvenile lake herring. The purse seine may, therefore, be useful in the

calibration of the fishing efficiency of other types of active gear (Barkley 1972; Murphy and Clutter 1972). The purse seine is also capable of capturing all sizes of fish alive and unharmed and, hence, can be used as a live capture technique for pelagic species.

Filtering efficiencies of the trawl, determined by the ratio of inside-net to outside-net flowmeter readings, is about 96% (n = 468 S = 1.62%). The flow across the mouth of the net is assumed to be laminar and uniform, although verification of this would require flow velocity measurement at points along the net diameter (Tranter and Smith 1968, p. 44). The trawl net is believed to retain all of the smallest larvae encountered, but avoidance of this gear by larger larvae represents a limitation for quantitative sampling. Coregonids of 15-20 mm length may be capable of considerable avoidance.

Clogging and fouling of the trawl nets by zooplankton and algae can be acute and place further constraints on the efficiency of this gear, limiting the length of each tow and the time of year in which the trawls can be effectively used. If fouling is evident, the nets require frequent washing. Clogging can create a handling problem and a resultant delay between tows. Paired flowmeters, one inside and one outside the net, will detect clogging as can remote recording of the flow rate through the net during a tow.

The purse seine, at times and in areas of high zooplankton production, particularly of *Holopedium gibberum*, also can become partly clogged producing extended set times and extra handling of the catch. This gear, however, can be reset without extensive prewashing and the presence of abundant zooplankton, while an inconvenience, does not compromise its efficiency.

Deployment and retrieval of the purse seine, while labour intensive, is easily performed by two people in about 7-8 min, after simple procedural details are learned. Use of the seine is limited to times when wind speeds do not exceed 15-20 knots. A complete set, including sorting of catch, requires an average of 25 min.

The larval trawls also require a 5-6 m work boat and two people. When properly adjusted, this gear is very easily operated, with tows of 5 min in duration optimally requiring about 15 min to complete, including the removal and sorting of the catch.

While operating costs on a per sample basis are slightly higher for the purse seine, this gear can be built using nylon insect screening, for less than $1,000. Two trawl-net assemblies and towing hardware can be assembled for about $3,000. These amounts do not include flowmeters and a remote readout which add over $4,500 to the cost of this gear.

CONCLUSIONS

The bridle-less trawl and fine-mesh purse seine were developed specifically to sample pelagic coregonine larvae in lakes using relatively small boats. Both gears have proven effective, but both have limitations related to accessibility to certain habitats, ease of handling, and fish avoidance. Complementary use of these gears, however, overcomes most of the problems associated with sampling the pelagic larvae of lake whitefish and lake herring in small lakes. The trawl is effective during early spring when the larvae are most abundant in nearshore areas, avoidance is low and clogging by zooplankton is minimal. The purse seine is more effective in late spring, when avoidance is greater, zooplankton density is high and the larvae have moved offshore. Incidental catches of larval burbot, white sucker, *Catostomus commersoni*, and yellow perch by both gears indicate their general effectiveness for pelagic species. For quantitative sampling, the trawls appear to be two- to three-fold more effective than bridled nets. For example, catches using a Faber net of similar diameter (Cucin and Faber 1985) produced geometric mean catches of lake whitefish and lake herring in Lake Opeongo that were only 1/3 to 1/2 those in the bridle-less trawl and the former only infrequently captured larvae greater than 20 mm. Trawl design, including hydro-dynamics and visibility,

appears to have a major influence on catchability for relatively small coregonine larvae, as has been clearly established for other species (e.g. Clutter and Anraku 1968; Noble 1970; Murphy and Clutter 1972; Krasovskaya and Sharpiro 1982). Our trawl design, however, is particularly effective, especially in nearshore areas where navigational hazards are common and high speed operation is often not practical.

POSTSCRIPT

Subsequent to testing the fine-mesh purse seine, we constructed two additional modified versions: one being 8 m deep x 31.5 m long and the other 9 m deep x 46.6 m long. We found the longest and deepest net to be more effective than the other two nets, but it is more difficult to handle and can only be used in the deeper strata (>9 m). All three purse seines, however, proved to be effective gears in Lake Opeongo for pelagic coregonines that otherwise have been difficult to sample effectively.

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